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NOTES ON THE MANUFACTURE OF ENAMEL BRICK WITH SOME INVESTIGATIONS ON ENAMEL BRICK SLIPS

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NOTES ON THE MANUFACTURE OF ENAMEL BRICK WITH SOME INVESTIGATIONS ON ENAMEL BRICK SLIPS.

BY

R. T. Stull, Urbana, Ill.

Aside from the contribution by Barringer in Volume V of our Transactions, very little literature can be found of material assistance to the prospective manufacturer of enamel brick.

Although the fundamental principles of ceramics apply to the manufacture of enamel brick, they have not been clearly pointed out in this line of business; besides, there are problems peculiar to the trade which need more thorough investigation.

The majority of men in America, who are in charge of the manufacturing end, are of foreign birth. They have brought their experiences and recipes with them, and have gone through the painful experiences of applying them to our conditions. This has been largely responsible for the prevailing belief that "we must go abroad to get clays for our slips."* If all Europe should pass stringent laws prohibiting the exportation of her clays, it is not probable that the American white ware potters and enamel brick makers would go out of business, nor make any great sacrifices in the quality of their products.

Clays suitable for enamel brick bodies should possess low shrinkages, good bond, be free from warping and cracking, stand up well at cone 4 or higher, and burn to a light color comparatively free from iron spots.

The plastic fireclays are well suited to this purpose. It is quite essential, however, to reduce their shrinkages by the addition of flint clay or grog. The majority of body mixes vary from 60 to 80 plastic and 40 to 20 non-plastic

* Instead of "engobe" the writer prefers to use the word "slip" because it is the term universally understood by enamel brick makers.

parts. Some clays will carry a small percent of sand without material injury. One mixture which has been in use for several years is composed of 70 parts plastic clay, 20 parts grog, and 10 parts crushed sand stone.

METHODS OF MANUFACTURE.

In general, two different processes of manufacture are recognized, viz., one fire and two fire. In both one and two fire ware, the methods of applying the veneer are practically the same, the distinguishing feature being that, in the two fire process, the brick are first biscuited at a low temperature before the veneer is applied. Quite recently mechanical appliances have been introduced which promise to make some radical changes in the manufacture of enamel brick. For the present work, the methods of manufacture will be divided into two general groups, according to the methods of application of the veneer.

I. Hand Dipping Process.
- (a) Single Fire:
  1. Dipping Stiff Mud Brick,
  2. Dipping Leather Hard Brick,
  3. Dipping Bone Dry Brick.
- (b) Two Fire:
  1. Dipping Biscuited Brick.

II. Mechanical Veneering Process.
- (a) Single Fire:
  1. Veneering Stiff Mud Column and Wire Cutting.

A favorite method of making enamel brick in Europe is by dipping a stiff-mud wire-cut brick. The face of a first quality enamel brick must be as near perfect as it is possible to make it. Since the brick are not repressed, the die is watched with the greatest care, and frequently lined up to normal size in order to take up the wear.

It is important that the brick be cut straight. A method in vogue is to cut the column into blocks which

are dipped, and after the slip has hardened sufficiently, the blocks are "squared" on a hand cutting table. This is also an effective way of removing the excess slip on the sides.

Although this method has not been exploited to any extent in America, it has many advantages well worth investigating: 1. Repressing and consequent flaking of the slip due to oil on the surface are avoided. 2. There is a better bond between slip and body since the two shrink together in drying. 3. The necessity of storing the brick until they reach leather hard consistency is eliminated.

In the leather hard method, the brick are allowed to harden by partial drying until nearly all drying shrinkage has ceased before they are dipped. The brick may be formed on a soft-mud machine, or "slush" molded by hand in wooden molds, hardened down to a stiff-mud consistency and re-pressed, or, more commonly, made stiff mud on a plunger or auger machine, wire cut, and re-pressed. Owing to the variation in size and shape, the soft-mud machine method is to be recommended only where two grades of brick are to be made. By sorting the brick as they come from the repress, those which are true in form and size can be used for enameling and the remainder burned for builders.

The process of slush molding and repressing by hand is very similar to that for hand made fire brick, except that more care is taken in filling and dumping the molds and greater care exercised in repressing.

The advantages in repressing are that the brick can be "squared up," panelled and the firm's name stamped on the side. With the stiff-mud brick not subjected to the repress, the brick can be judiciously cored and the lettering stamped on the back side of the column by a roller.

A few plants are glazing bone dry brick. Although sold as enamel brick in some cases, they are in reality

nothing more than glazed brick, and should be classed as such.

To the writer's knowledge, there is not a plant at the present time successfully making a white enamel brick by dipping a bone dry body in slip and glaze. It is doubtful whether this method will ever be a success owing to difficulties encountered in cracking and flaking of the slip.

In the two fire process the brick may be made soft-mud repress, stiff-mud wire-cut, stiff-mud repress or dry-press process. The brick are first biscuited at heats ranging from cone 08 to cone 01, then dipped in slip and glaze and given the glost fire at cones 3 to 9. A few plants making dry pressed front brick from fire clays are enamelling their culls, which are too soft for the market or off in color but otherwise having true faces.

Methods of Dipping.

In some cases the brick are given one dip in the slip and one in the glaze, but in most cases the brick are given two dips in the slip and one in the glaze. A factory which has been brought to the writer's notice sprays on the first coat and dips the second one. Two slips of different composition are sometimes employed, the first dip being made in a slip comparatively high in ball clay and correspondingly low in China clay or kaolin. Over this a second coat is applied composed of materials giving a much whiter surface.

The thickness of the slip is an important factor. It is essential that it be applied thick enough in order to form a smooth coating and to hide the character of the body underneath. In the two fire process the brick may be porous enough to take on a sufficient coating in one dip, but for stiff-mud and leather-hard bodies, one dip is seldom sufficient, except in cases where a more or less opaque glaze is applied over. The proper thickness of the slip under ordinary conditions is from three-hundredths to five-hundredths of an inch. Where the slip is thin, the

differences in shrinkage and expansion of body and slip are balanced by the elasticity of the slip, thus preventing rupture. If the coating of slip is too thick, its shrinkage and expansive forces may cause cracking, crazing or flaking.

The glaze applied over the slip should be quite viscous so as to prevent excessive flow and beading along the edges, and to overcome the absorption of the glaze by the slip and the consequent vitrifying of the slip which would cause the dark color of the body to show through.

Defects Appearing After Dipping.

The principal defects which appear after dipping before the brick enter the kiln are:

1. Pinholes.
2. Flaking.
3. Cracking.

Pinholes.

Pinholes may occur from four causes: 1. Using a freshly made slip. 2. Pinholes or cavities in the surface of the brick. 3. Dust on the face to be dipped. 4. Bad dipping.

The writer has seen pinholes appear repeatedly by dipping brick in a freshly made slip. After ageing the slip for a short time, pinholes from this cause disappeared. A week's ageing of the slip is usually sufficient.

After dipping, the pinholes do not appear until the "water gloss" of the surface begins to disappear. Bubbles which appear on the surface break, leaving small cavities in the surface.

2. Air is entrapped in small cavities or pores in the dipped surface. As the water in the slip is absorbed by the brick, the air in these small cavities is forced out, passing up through the slip, thus causing pinholes.

3. In dipping a dusty surface, air is entrapped in films around the dust particles and in cavities between

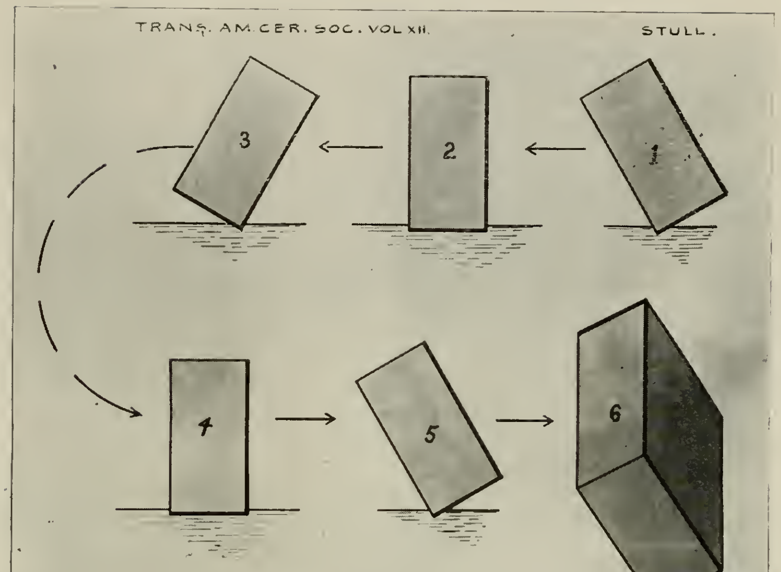
them. As the water in the slip slowly creeps over the surface of these particles, the air is released and rises to the surface.

In order to overcome pinholes caused by dust or minute cavities in the surface, brick makers resort to "scrubbing;" i. e., the surfaces to be enameled are brushed over with a stiff brush dipped in water, or more commonly, in a slip diluted with water. Other recipes which have been in use are: water, slip and glue; water, slip and molasses; water, fire clay and white slip.

4. Air may be entrapped by bad dipping. This occurs if a flat surface of the brick meets the surface of the slip when first immersed.

A good method of dipping is to hold the back of the brick in the palm of the hand with face to be dipped, down. By allowing one edge of the brick to first meet the surface of the slip as in position 1, the slip is washed across the face by a rocking motion through 2 to 3. Then by the reverse motion (without removing the brick from the slip), the brick is passed back through 4 to 5. The end of the brick farthest from the operator is then raised as in position 6, which allows the excess slip to run down the edge and leave at the corner as it is raised from the slip. The brick is then quickly inverted and slid onto a bench.

The dipping should be done by an easy swinging motion to and fro without a halt in the operation. The time required for a single dip is from three to six seconds, and a careful dipper can perform the operation alternately right and left handed, getting very little slip over the edges.



Different Positions Of Brick In Dipping.
Fig 1

Flaking.

Flaking or shelling of the slip is due to lack of bond. It may occur soon after dipping or may not appear until the brick are subjected to the fire. Lack of bond may be caused by oil or dust on the surface, or by unequal shrinkage of slip and body. It is most frequently caused by too low shrinkage of the slip, but in some cases it is caused by too high shrinkage of the slip. In the latter case cracking and flaking will appear on the same surface.

Scrubbing the surface before dipping not only prevents pinholes, but also assists adhesion by removing dust and oil which may cause an otherwise good slip to flake.

Slips too low in plastic clay, or slips too high in kaolin or China clay which are short or weak in character will cause flaking. Where flaking is due to low shrinkage, the remedy is to increase the percent of plastic clay and de-

crease the non-plastic portion. Where cracking and flaking occur, reduce the percent of clay and substitute part ball clay for China clay or kaolin.

The tendencies of ball clay are to increase shrinkage, impart greater adhesive power and render the slip more yielding or ductile by which it adjusts itself better to the brick, thus preventing rupture.

Some English recipes for slips require plaster of paris to overcome flaking. It is necessary in such cases to exercise care in burning, besides, the cause of rough, blistered and scummed glazes can frequently be traced to plaster in the slip. The use of plaster to prevent flaking is unnecessary, since good reliable slips can be had without it.

Cracking.

Cracking may be caused by: 1. Excessive shrinkage of the slip. 2. Too thick a coating of slip. 3. Too fine grinding of slip. 4. In dipping leather hard, allowing the brick to become too dry before dipping. 5. Using clays which are weak or have low tensile strength.

Cracking may be overcome by substituting a clay of low shrinkage for one of higher; or increasing the non-plastic portion and decreasing the plastic part, such as increasing flint and feldspar or Cornwall stone, or replacing part raw clay with calcined clay.

Blunging the slip instead of grinding is to be recommended. The use of a small quantity of carbonate of soda or borax is found to be beneficial to overcome cracking. The proper amounts of these soluble materials to use is an important factor and varies in different slips, hence the amount should be determined experimentally. Slips high in clay require more than slips low in clay.

Mechanical Methods of Applying Slip.

The most universal method of applying slip and glaze is by hand dipping and removing the surplus on the sides by scraping with a knife or scratching with a fine wire brush. Quite recently a leading enamel brick plant has

been experimenting with a dipping machine similar in construction to that used for dipping wall tile. The machine is made somewhat larger, with a few minor changes in its construction in order to make it more suitable for its new purpose.

The automatic veneering process is one which has a great future. The process consists in veneering a column of stiff mud clay after it issues from a die. For this purpose a veneering device is attached to the end of the die or placed in front of it for spreading the slip in a layer about one-sixteenth of an inch thick upon the faces to be veneered.

Although there are four American patents on devices for veneering a column of clay, but one of these seems to be successful for the manufacture of enameled brick, viz., the Ramsay patent, which has recently been brought to public notice by an infringement suit.

The veneering device consists of two rectangular frames A and B, called slickers, having two plates between as C, one at each side. These slickers are fastened together by two bolts at each side as DD. The apparatus is supported by the die and about one inch in front of it on two rods E, one at each side. Figs. 2 and 3 represent the apparatus rigged for making stretchers, in which case the top of the column is veneered. Fig. 4, a vertical section across the column, shows the arrangement for making quoins, in which case the top and one side of the column are veneered. The same principle is used for making bull nose and other shapes.

"A" is the surface preparing slicker having the same inside dimensions as the delivery end of the die. "B" is the slip slicker and is five sixty-fourths of an inch larger than the surface preparing slicker at all points where the slip is to be applied to the column. "S," the slip which is pugged to about the same consistency as clay used for pressing white ware, is placed upon the column between A and B. As the column moves forward the slip adheres

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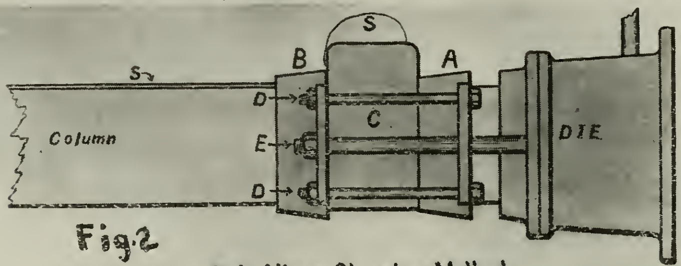

Fig. 2

Side View Showing Method Of Veneering Top Of Column.

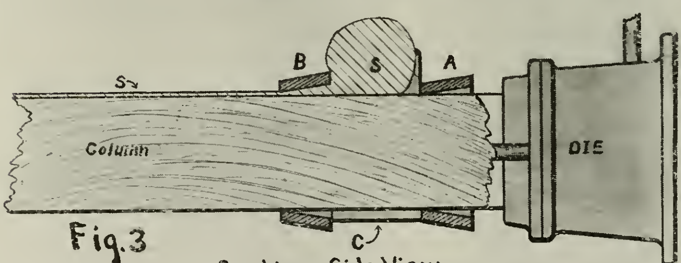

Fig. 3

Section, Side View.

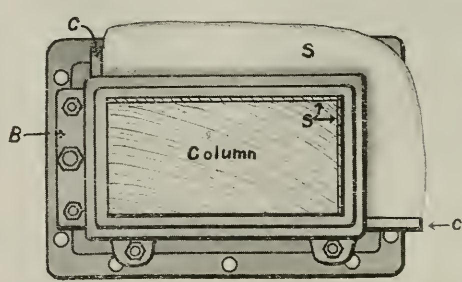

Fig. 4

End View Showing Method Of Veneering Top And Side Of Column.

to it and rolls over and over, unwinding as it were, and is spread in a coating about one-sixteenth of an inch in thickness by the slip slicker "B."

The column is cut into brick on a hand cutting table of special design and dried on a hot floor. The bricks are loaded on trucks and the glaze applied by a large sprayer having the air and glaze under a pressure of forty to sixty pounds. The brick are then set and burned single fire.

Setting.

Of the three methods of burning, viz., open fire, burning in muffles and burning in saggers, the open fire method is most economical but requires considerable care and skill in setting. Some brick makers set the brick in piers, but the writer prefers setting in benches extending across the kiln. In two fire ware the brick may be set on the flat as described by Barringer,[1] but for single fire ware this method causes considerable loss in cracking owing to shrinkage. In order to overcome this difficulty, the stretchers on the outside of the benches are set on end and shapes set flat in the middle in piers, (Fig. 5).

In the single fire method the brick should go into the kiln bone dry. In the writer's experience, brick which were set wet frequently came out with a dry, rough surface as though the glaze were underfired. At other times the glaze would be blistered or badly scummed. These brick were called by the workmen "steamed brick." Repeated burning of these brick made no appreciable difference in their appearance.

It is probable that these brick being wet, took up sulphur dioxide from the kiln gases, which in turn oxidized to sulphuric acid. This naturally would combine with lime and zinc oxide present in the glaze, and since the kilns were burned oxidizing throughout, the sulphates would naturally remain as such.

[1] Trans. A. C. S., Vol. V, p. 273.

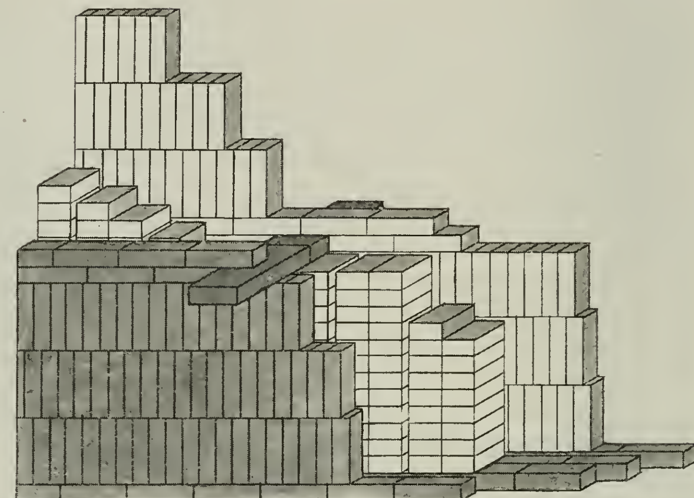

Fig. 5.
Portion of Bench, Quoins in the Middle, Stretchers Outside.

INVESTIGATIONS BY THE WRITER.

(Ceramic Laboratory, University of Illinois)

The following work comprises some investigations on enamel brick slips applied to leather hard, bone dry and biscuit bodies between the limits

25 to 75 parts clay materials,
75 to 25 parts non-plastic materials.

The ceramic materials employed were:

Georgia kaolin,
North Carolina kaolin,
Tennessee ball clay (No. 1),
Brandywine feldspar,
Ohio flint (8 hr. grind),
M. G. R. English China clay,

Pikes English ball clay (No. 20),
English Cornwall stone,
Carbonate of soda.

The objects of the work were to determine the range of good slips within the above named limits, to study the causes and remedies of defects, and to compare the slip making values of some of the English materials with those of a few American materials.

If a brick is to come from the kiln as a No. 1 article, it must first enter the kiln in No. 1 condition. The first step undertaken in the work was, to determine the ratios of plastic to non-plastic portions for slips which would fit the bodies perfectly in dipping, and which were to be used as bases for making the slips for the burning trials. For this purpose series 27, 28, 29 and 30 were constructed.

Carbonate of soda was kept constant at one percent in all slips throughout the work. All slips contained ten percent of ball clay, two different ball clays being employed for comparison.

The slips were weighed dry, blunged, passed through a 100 mesh screen, set at 1500 to 1520 B & L hydrometer, and placed in sealed jars and allowed to age for one week.

The body for the briquettes was composed of 70 parts plastic fire clay and 30 parts 16 mesh grog. The trials were made stiff mud on a small auger machine and wire cut.

The trials received two dips in the slip, the dipped surface first being scrubbed with two parts water and one part of the slip to be applied.

SERIES 27.
Ga. Kaolin—No. 1 Tenn. Ball.

No.	Kaolin	Tenn. No. 1 Ball.	Flint	Carbonate of Soda	On Leather Hard	On Bone Dry	On Biscuit	Basis for Series
185	15	10	75	1	Flaked Flaked	Flaked Flaked	Good	31 and 50
186	25	10	65	1		Cracked	Cracked	....
187	35	10	55	1	Flaked Cracked	Cracked	Cracked Flaked	....
188	45	10	45	1	Cracked	Cracked	Cracked	....
189	55	10	35	1	Cracked	Cracked	Cracked	....
190	65	10	25	1	Cracked	Cracked	Cracked	....

In series 27 all slips flaked on leather hard trials, and flaked and cracked on bone dry. Slip No. 185, containing 15 Georgia kaolin and 75 flint, was good on biscuit. This slip was selected as the basis for Series 31 and 50. All other slips cracked and flaked.

SERIES 28.
N. C. Kaolin—No. 1 Tenn. Ball.

No.	N. C. Kaolin	Tenn. No. 1 Ball	Flint	Carbonate of Soda	On Leather Hard	On Bone Dry	On Biscuit	Basis for Series
191	15	10	75	1	Flaked	Flaked	Good	32 and 51
192	25	10	65	1	Flaked	Flaked	Good	33 and 52
193	35	10	55	1	Flaked	Flaked	Good	34 and 53
194	45	10	45	1	Flaked	Flaked	Good	35 and 54
195	55	10	35	1	Flaked	Flaked	Good	36 and 55
196	65	10	25	1	Flaked	Flaked	Good	37 and 56

In Series 28 all slips fit perfectly on biscuit but flaked on bone dry and leather hard bodies.

SERIES 29.
N. C. Kaolin—English Ball.

No.	N. C. Kaolin	English Ball	Flint	Carbonate of Soda.	On Leather Hard	On Bone Dry	On Biscuit	Basis for Series
197	15	10	75	1	Flaked	Good	Good	38 and 57
198	25	10	65	1	Flaked	Good	Good	39 and 58
199	35	10	55	1	Flaked	Good	Good	40 and 59
200	45	10	45	1	Flaked	Doubtful	Good	41 and 60
201	55	10	35	1	Good	Cracked	Good	42 and 61
202	65	10	25	1	Good	Cracked	Good	43 and 62

Series 29 is the same as Series 28 except that Pikes No. 20 English ball clay replaces Tennessee ball. In this series all slips work perfectly on biscuit, the three lowest in clay fit bone dry, the others cracked. The two highest in clay fit perfectly on leather hard.

SERIES 30.
English China—English Ball.

No.	English China	English Ball	Flint	Carbonate of Soda	On Leather Hard	On Bone Dry	On Biscuit	Basis for Series
203	15	10	75	1	Flaked	Good	Good	44 and 63
204	25	10	65	1	Good	Good	Good	45 and 64
205	35	10	55	1	Good	Cracked	Cracked	46 and 65
206	45	10	45	1	Good	Cracked	Cracked	47 and 66
207	55	10	35	1	Good	Cracked	Cracked	48 and 67
208	65	10	25	1	Good	Cracked	Cracked	49 and 68

Slips containing 15 to 25 China clay were good on biscuit and bone dry, the remainder cracked. The slip lowest in clay flaked on leather hard, the remainder were good.

Limits of Plastic and Non-Plastic for Dipping.

Selecting all slips which are good in the above four series, we find that for leather hard, perfect fitting slips in dipping lie within the range:

Clay ....35 to 75
Non-plastic ....65 to 25

For dipping bone dry:—

Clay ....25 to 45
Non-plastic ....75 to 55

For dipping biscuit:—

Clay ....25 to 75
Non-plastic ....75 to 25

Undoubtedly slips higher in clay would dip well on leather hard trials, but these were considered as impractical on account of crazing after burning, as will be shown later on.

Slips lower in clay would probably dip perfectly on biscuit, and here again we find crazing.

After determining the limits of plastic and non-plastic portions for perfect fitting slips in dipping, the next step in the work was to select each of the perfect working slips as a basis of a series in which the non-plastic portion was varied between flint and flux.

Series 31 and 50 are the only two containing Georgia kaolin which dipped well on biscuit. The other series are arranged in six groups, the flux in the first three being feldspar. The other three groups are a repetition of the first three, except that Cornwall stone was used as the flux in place of the feldspar.

Three different burns were made, viz., cones 4, 6 and 8. The variation in the kiln was such as to give cone 2 in the coolest part of the cone 4 burn, and cone 9 in the hottest part of the cone 8 burn. Trials were set on edge in tile saggers. Three trials of each slip were placed in each burn, two having glaze No. 5[1] applied over and the third slip left unglazed. Cones were also placed in each sagger.

A portion of each slip was cast ¼ x ½ x 1¾ inches in plaster molds. These cast trials were placed in the saggers with the dipped trials and used for determining the porosity of the slips. It was desirable to know what relation porosity had to the ability of slips to stand the freezing test. This part of the work is under way and not completed at the present writing.

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[1] Trans. A. C. S., Vol. X, p. 218.

SERIES 31.

(On Biscuit)

No.	Constant	Flint	Spar	Cone 5	Cone 7	Cone 9
209	Ga. Kaolin ....15 Tenn. Ball No. 1....10 Carbonate of Soda... 1	60	15	Crazed	Crazed	Crazed
210		55	20	Crazed	Crazed	Crazed
211		50	25	Crazed	Crazed	Crazed
212		45	30	Crazed	Crazed	Crazed
213		40	35	Crazed	Crazed	Crazed
214		35	40	Crazed	Crazed	Crazed
215		30	40	Crazed	Crazed	Crazed
216		25	50	Crazed	Crazed	Crazed

All are good smooth slips but crazed. The glaze tends to decrease crazing of the slip. Crazing of slip increases with increase in temperature. Crazing decreases with replacement of flint by feldspar. No. 209 is a beautiful white, the whitest slip in the entire work.

Group I—Series 32 to 37.

SERIES 32.

(On Biscuit)

No.	Constant	Flint	Spar	Cone 6	Cone 7	Cone 9
217	N. C. Kaolin.......15 Tenn. Ball No. 1....10 Carbonate of Soda... 1	60	15	Crazed	Crazed	Crazed
218		55	20	Crazed	Crazed	Crazed
219		50	25	Crazed	Crazed	Crazed
220		45	30	Crazed	Crazed	Crazed
221		40	35	Crazed	Crazed	Crazed
222		35	40	Crazed	Crazed	Crazed
223		30	45	Crazed	Crazed	Crazed
224		25	50	Good	Slightly Crazed	Good

All are good slips except for crazing. Crazing decreases from 217 to 224 due to replacement of flint by

feldspar. Crazing of slips increase with increase in temperature. No. 224 is highly vitrified at Cone 9. This slip can be called good at Cone 6, but is too translucent at Cone 9. Slips are slightly cream colored.

SERIES 33.

(On Biscuit)

No.	Constant	Flint	Spar	Cone 6	Cone 7	Cone 9
225	N. C. Kaolin.........25 Tenn. Ball No. 1.....10 Carbonate of Soda... 1	50	15	Good	Good	Good
226		45	20	Good	Good	Good
227		40	25	Good	Good	Good
228		35	30	Good	Good	Good
229		30	35	Good	Good	Good
230		25	40	Good	Good	Good
231		20	45	Good	Good	Good
232		15	50	Good	Good	Good

All slips work perfectly. The 10% increase in clay in this series above that in Series 32 has eliminated crazing entirely. Slips 229 to 232 are translucent at cone 8. Slips are a light cream in color.

SERIES 34.

(On Biscuit)

No.	Constant	Flint	Spar	Cone 6	Cone 7	Cone 9
233	N. C. Kaolin.........35 Tenn. Ball No. 1.....10 Carbonate of Soda... 1	45	10	Good	Good	Good
234		40	15	Good	Good	Good
235		35	20	Good	Good	Good
236		30	25	Good	Good	Good
237		25	30	Good	Good	Good
238		20	35	Good	Good	Good
239		15	40	Good	Good	Good
240		10	45	Good	Good	Good

This series is similar to Series 33. No bad defects. Slips 237 to 240 are vitrified to a blue-white at Cone 9.

SERIES 35.

(On Biscuit)

No.	Constant	Flint	Spar	Cone 6	Cone 7	Cone 9
241	N. C. Kaolin.......45 Tenn. Ball No. 1....10 Carbonate of Soda... 1	40	5	Good	Good	Good
242		35	10	Good	Good	Good
243		30	15	Good	Good	Good
244		25	20	Good	Good	Good
245		20	25	Cracked	Cracked	Cracked
246		15	30	Cracked	Cracked	Cracked
247		10	35	Cracked	Cracked	Cracked

Slips are very good except a slight tendency to crack. Cracking increases with decrease in flint and increase in feldspar. Slips 245 to 247 are translucent at Cone 9. Nearly all the glazed trials are good. Glaze tends to overcome cracking of the slip.

SERIES 36.

(On Biscuit)

No.	Constant	Flint	Spar	Cone 6	Cone 7	Cone 9
248	N. C. Kaolin.......55 Tenn. Ball No. 1....10 Carbonate of Soda... 1	30	5	Good	Good	Good
249		25	10	Good	Good	Good
250		20	15	Good	Good	Good
251		15	20	Cracked	Cracked	Cracked
252		10	25	Cracked	Cracked	Cracked
253		5	30	Cracked	Cracked	Cracked

This series is similar to Series 35. The cracking, however, is a little more prominent.

SERIES 37.

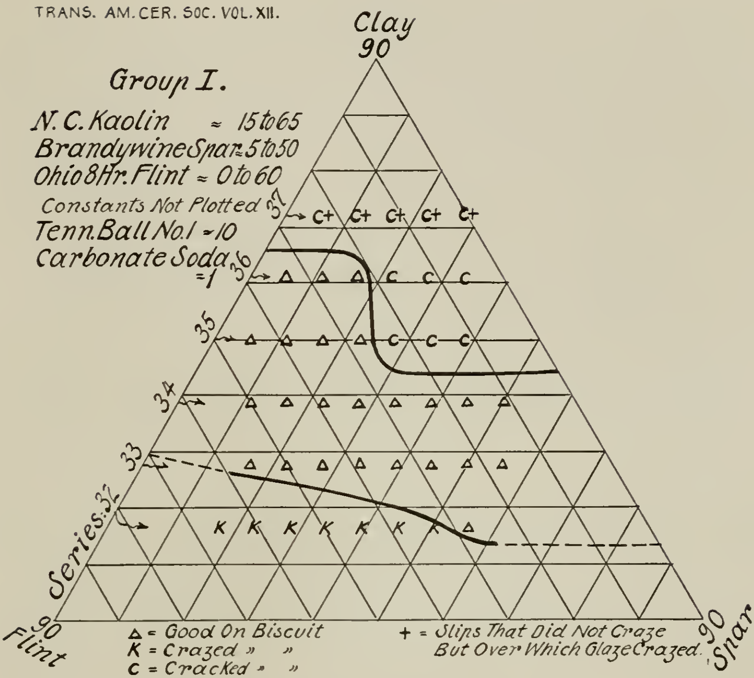
(On Biscuit)

Constant: N. C. Kaolin, 65; Tenn. Ball No. 1, 10; Carbonate of Soda, 1.

No.	Flint	Spar	Cone 3		Cone 6		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
254	20	5	Cracked	Crazed	Cracked	Good	Cracked	Cracked
255	15	10	Cracked	Crazed	Cracked	Good	Cracked	Good
256	10	15	Cracked	Crazed	Cracked	Crazed	Cracked	Good
257	5	20	Cracked	Crazed	Cracked	Crazed	Cracked	Good
258	0	25	Cracked	Crazed	Cracked	Crazed	Cracked	Good

All slips cracked. Glaze tends to prevent cracking of slip. Slips did not craze, but glazes crazed over slips in fine zig-zag lines. Increasing temperature of firing decreases crazing of the glaze.

The six different groups were plotted on tri-axial diagrams. In many cases the unglazed slips were defective and the same slips glazed were good. Only those slips were plotted as good which were sound both glazed and unglazed, and all such slips that were sound at one temperature, but may have been slightly defective at some other temperature, were plotted as good. Slips which were translucent (due to vitrification) but otherwise perfect were also plotted as good.



Conclusions on Group I.

Crazing: A high content of flint evidently causes crazing of the slip. Decreasing flint and increasing clay or feldspar, or both, decreases crazing. Increasing clay is more effective in overcoming crazing than increasing feldspar. With flint constant, decreasing clay and increasing feldspar, increases crazing. Crazing of the slip increases with increase in burning temperature.

A high content of clay does not cause the slip to craze, but causes the glaze applied over the slip to craze. Decreasing clay and increasing flint or feldspar, or both, in the slip decreases crazing of the glaze. Increasing the burning temperature decreases glaze crazing.

Cracking: Excessive clay in the slip causes cracking during burning. Decreasing clay and increasing flint or

feldspar, or both, decreases cracking. Increasing flint decreases cracking more effectively than increasing feldspar. With clay constant, decreasing flint and increasing feldspar increases cracking.

Good slips in this group on a biscuit body are found between the limits:

Georgia Kaolin	15 to 55	
Flint	10 to 50	
Feldspar	5 to 50	
Ball Clay	10	Constant
Carbonate of Soda	1	Constant

Group II. Series 38 to 43.

SERIES 38.

(On Biscuit)

Constant: N. C. Kaolin, 15; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Spar	Cone 3 Unglazed	Cone 3 Glazed	Cone 6 Unglazed	Cone 6 Glazed	Cone 8 Unglazed	Cone 8 Glazed
259	60	15	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed
260	55	20	Crazed	Crazed	Crazed	Crazed	Crazed	Good
261	50	25	Crazed	Crazed	Crazed	Good	Crazed	Good
262	45	30	Crazed	Crazed	Good	Good	Crazed	Good
263	40	35	Good	Good	Good	Good	Crazed	Good
264	35	40	Good	Good	Good	Good	Crazed	Good
265	30	45	Good	Good	Good	Good	Crazed	Good
266	25	50	Good	Good	Good	Good	Crazed	Good
267	20	55	Good	Good	Good	Good	Crazed	Good

Crazing of unglazed slips increases and crazing of glazed slips decreases with increase in temperature. Crazing decreases with increase in feldspar. Aside from crazing, slips fit perfectly. Slips 264 to 267 are translucent at Cone 6, due to vitrification. Slips 261 to 267 are translucent at Cone 9.

SERIES 38.

(On Bone Dry)

No.	Cone 3		Cone 5		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
259	Crazed Cracked	Crazed	Crazed Cracked	Crazed	Crazed Cracked	Good
260	Crazed Cracked	Crazed	Crazed Cracked	Good	Crazed Cracked	Good
261	Crazed Cracked	Crazed	Crazed Cracked	Good	Crazed Cracked	Good
262	Crazed Cracked	Good	Crazed Cracked	Good	Cracked	Good
263	Crazed	Good	Crazed Cracked	Good	Good ?	Good
264	Crazed	Good	Cracked	Good	Cracked	Good
265	Good	Good	Cracked	Good	Good ?	Good
266	Good	Good	Good	Good	Good ?	Good
267	Good	Good	Good	Good	Cracked	Good

Slips show a tendency to crack. Cracking does not seem to be influenced by variation in composition or heat treatment. Cracks extend down into the body about 1/32 to 1/16 of an inch.

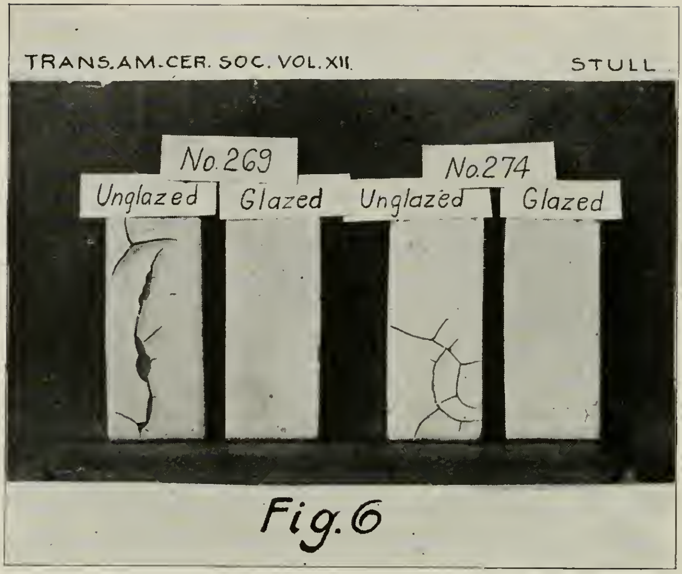
SERIES 39.

(On Biscuit)

Constant: N. C. Kaolin, 25; English Ball, 10; Carbonate of Soda, 1.

No	Flint	Spar	Cone 4		Cone 6		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
268	50	15	Good	Good	Good	Good	Cracked	Good
269	45	20	Good	Good	Good	Good	Cracked	Good
270	40	25	Good	Good	Good	Good	Cracked	Cracked
271	35	30	Good	Good	Good	Good	Good	Good
272	30	35	Good	Good	Good	Good	Good	Good
273	25	40	Good	Good	Cracked	Cracked	Cracked	Cracked
274	20	45	Good	Good	Cracked	Good	Good	Good
275	15	50	Good	Good	Cracked	Good	Good	Good

Slips have a slight tendency to crack, which increases with increase in feldspar and temperature. Glaze over the slip tends to prevent cracking. (See Fig. 6). All slips are opaque at Cone 6. Slips 272 to 275 are vitrified and translucent at Cone 8.



ILLUSTRATIONS OF GLAZE PREVENTING SLIPS FROM CRACKING.

SERIES 39.

(On Bone Dry)

No.	Cone 4		Cone 6		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
268	Cracked	Good	Cracked	Cracked	Cracked	Cracked
269	Cracked	Good	Cracked	Good	Cracked	Good
270	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
271	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
272	Cracked	Cracked	Cracked	Good	Cracked	Cracked
273	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
274	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
275	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked

Cracking quite bad; worse than series 38.

SERIES 40.

(On Biscuit)

Constant: N. C. Kaolin, 35; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Spar	Cone 4		Cone 6		Cone 9	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
276	45	10	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
277	40	15	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
278	35	20	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
279	30	25	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
280	25	30	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
281	20	35	Cracked	Cracked	Cracked	Good	Cracked	Cracked
282	15	40	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
283	10	45	Cracked	Good	Cracked	Good	Cracked	Good

Cracking of slips very bad. Cracking decreases with increase in feldspar. Glaze tends to prevent cracking of the slip. All slips are opaque at Cone 4. Slips 281 to 283 at Cone 6, and 279 to 283 at Cone 9 are vitrified.

SERIES 40.

(On Bone Dry)

No.	Cone 4	Cone 6	Cone 9
276	Cracked	Cracked	Cracked
277	Cracked	Cracked	Cracked
278	Cracked	Cracked	Cracked
279	Cracked	Cracked	Cracked
280	Cracked	Cracked	Cracked
281	Cracked	Cracked	Cracked
282	Cracked	Cracked	Cracked
283	Cracked	Cracked	Cracked

All slips both glazed and unglazed crack badly. Cracking extends through slips into the body.

SERIES 41.

(On Biscuit)

Constant: N. C. Kaolin, 45; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Spar	Cone 5		Cone 7		Cone 9	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
284	35	10	Cracked	Good	Cracked	Good	Good	Cracked
285	30	15	Good	Good	Cracked	Good	Good	Good
286	25	20	Good	Good	Cracked	Cracked	Cracked	Cracked
387	20	25	Cracked	Good	Cracked	Good	Cracked	Good
288	15	30	Good	Good	Good	Cracked	Good	Good
289	10	35	Cracked	Cracked	Cracked	Good	Cracked	Cracked

Slips which cracked showed a tendency to curl up and flake. All slips are opaque at Cone 9.

SERIES 42.

(On Biscuit)

Constant: N. C. Kaolin, 55; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Spar	Cone 5		Cone 7		Cone 9	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
290	30	5	Cracked	Good	Cracked	Good	Cracked	Good
291	25	10	Cracked	Good	Cracked	Cracked	Cracked	Cracked
292	20	15	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
293	15	20	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
294	10	25	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
295	5	30	Cracked	Good	Cracked	Good	Cracked	Good

This series acts very similarly to Series 41.

SERIES 42.

(On Leather Hard)

No	Cone 5	Cone 7	Cone 9
290	Good	Good	Good
291	Good	Good	Good
292	Good	Good	Good
293	Good	Good	Good
294	Good	Good	Good
295	Good	Good	Good

All slips are good both glazed and unglazed, except that the glaze flakes from the slip slightly. Slips, however, fit perfectly. All slips are opaque at Cone 9.

SERIES 43.

(On Biscuit)

Constant: N. C. Kaolin, 65; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Spar	Cone 5		Cone 7		Cone 9	
			Unglazed	Glazed	Ungl-zed	Glazed	Unglazed	Glazed
296	20	5	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
297	15	10	Cracked	Cracked	Cracked	Good	Cracked	Cracked
298	10	15	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
299	5	20	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
300	0	25	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked

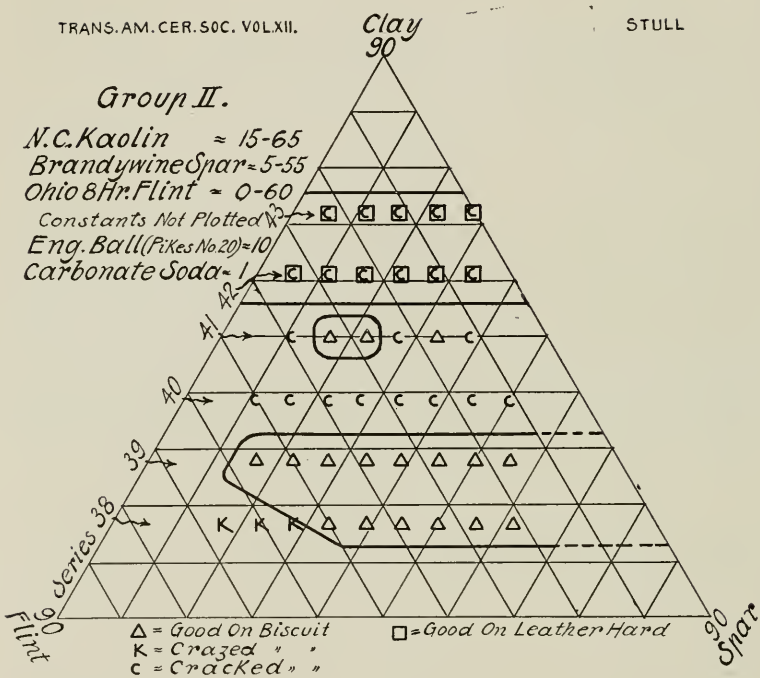
Cracking is very bad. Slips also flake some but not badly. All slips are opaque at Cone 9.

SERIES 43.

(On Leather Hard)

No.	Cone 5	Cone 7	Cone 8
296	Good	Good	Good
297	Good	Good	Good
298	Good	Good	Good
299	Good	Good	Good
300	Good	Good	Good

All slips work perfectly both glazed and unglazed. Glaze, however, flaked from slips; otherwise all trials were sound.



Conclusions on Group II.

The conclusions drawn with respect to crazing and cracking in Group I apply to Group II. There is a tendency of slips high in clay to flake as well as crack on biscuit body. Series 42 and 43, which are applied to leather hard body as well as biscuit, gave good results on the leather hard body, but cracked on biscuit.

In comparing the tri-axial diagram of Group II with that of Group I it is observed that the substitution of Pikes No. 20 English ball clay for Tennessee ball clay No. 1, has given a much smaller field of good slips on biscuit body; cracking has increased and crazing of slips decreased. Good slips are obtained which possess satisfactory working qualities on leather hard body. None of the slips were good on bone dry body.

The limits of composition for good slips on biscuit found in this group are:

North Carolina Kaolin	15 to 25	
Brandywine Feldspar	15 to 55	
Ohio Flint	15 to 50	
Pikes No. 20 Eng. Ball Clay	10	Constant
Carbonate of Soda	1	Constant

The limits for good slips on leather hard body are:

North Carolina Kaolin	55 to 65	
Brandywine Feldspar	5 to 30	
Ohio Flint	0 to 30	
Pikes No. 20 Eng. Ball Clay	10	Constant
Carbonate of Soda	1	Constant

GROUP III—SERIES 44 TO 49.

SERIES 44.

(On Biscuit)

Constant: English China, 15; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	par	Cone 5 Unglazed	Cone 5 Glazed	Cone 6 Unglazed	Cone 6 Glazed	Cone 8 Unglazed	Cone 8 Glazed
301	60	15	Cracked Crazed	Crazed	Cracked Crazed	Crazed	Cracked Crazed	Crazed
302	55	20	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed
303	50	25	Cracked Crazed	Crazed	Cracked Crazed	Crazed	Cracked Crazed	Crazed
304	45	30	Crazed Cracked	Crazed	Cracked Crazed	Good	Cracked Crazed	Crazed
305	40	35	Crazed	Crazed	Cracked	Good	Crazed	Good
306	35	40	Cracked Crazed	Crazed	Crazed Cracked	Crazed	Crazed Cracked	Crazed
307	30	45	Crazed	Crazed	Crazed	Crazed	Crazed	Good
308	25	50	Crazed	Crazed	Cracked	Good	Good	Good
309	20	55	Crazed	Crazed	Crazed	Good	Good	Good

All slips crazed. Glaze also crazed at low temperatures. Increase of temperature decreases crazing of the glaze. The glaze tends to prevent crazing of the slip. Very little difference is noticed in crazing of the slip due to difference in heat treatment. A decrease in crazing is noticeable with reduction of flint and increase in feldspar. Cracking is due to excessive fire shrinkage. Slips are all quite dense.

SERIES 44.

(On Bone Dry)

No.	Cone 5		Cone 6		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
301	Cracked Crazed	Cracked Crazed	Cracked Crazed	Cracked Crazed	Cracked Crazed	Cracked Crazed
302	Cracked Crazed	Cracked Crazed	Crazed	Crazed	Cracked Crazed	Cracked Crazed
303	Cracked Crazed	Cracked Crazed	Cracked Crazed	Crazed Cracked	Cracked Crazed	Cracked Crazed
304	Cracked Crazed	Cracked Crazed	Cracked Crazed	Crazed Cracked	Cracked Crazed	Cracked Crazed
305	Cracked Crazed	Cracked Crazed	Cracked Crazed	Crazed Cracked	Cracked Crazed	Cracked Crazed
306	Crazed Cracked	Cracked Crazed	Cracked Crazed	Crazed Cracked	Cracked Crazed	Cracked Crazed
307	Crazed Cracked	Cracked Crazed	Crazed	Crazed Cracked	Cracked Crazed	Cracked Crazed
308	Crazed Cracked	Cracked Crazed	Cracked Crazed	Crazed Cracked	Cracked	Cracked
309	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed

In general, slips crack badly. Cracking extends down into body. Crazing is the same as observed on biscuit. Nearly all slips are vitrified. Nos. 304 to 309 are glossed in the unglazed condition at Cone 8.

SERIES 45.

(On Biscuit)

Constant: English China, 25; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Spar	Cone 5		Cone 6		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
310	50	15	Crazed Cracked	Good	Good	Good	Good	Cracked
311	45	20	Crazed Cracked	Crazed	Cracked	Cracked	Cracked	Cracked
312	40	25	Crazed	Good	Good	Good	Good	Cracked
313	35	30	Good	Good	Good	Cracked	Good	Cracked
314	30	35	Cracked	Good	Crazed	Good	Cracked	Good
315	25	40	Cracked	Good	Crazed	Cracked	Cracked	Cracked
316	20	45	Cracked	Cracked	Good	Good	Cracked	Cracked
317	15	50	Good	Good	Good	Good	Cracked	Cracked

Crazing of slips decreases with decrease of flint and

increase of feldspar. Crazing also increases with increase in temperature. Slips are all opaque at Cone 4. No. 317 is translucent at Cone 6. Slips 313 to 317 are translucent at Cone 8.

SERIES 45.

(On Bone Dry)

No.	Cone 4		Cone 6		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
310	Cracked Crazed	Cracked	Cracked Crazed	Good	Good	Cracked
311	Cracked	Cracked	Cracked Crazed	Cracked	Cracked	Cracked
312	Cracked	Cracked	Cracked Crazed	Cracked	Cracked	Cracked
313	Good	Cracked	Cracked Crazed	Cracked	Cracked	Cracked
314	Cracked	Cracked	Cracked Crazed	Cracked	Cracked	Cracked
315	Cracked	Cracked	Cracked Crazed	Cracked	Cracked	Cracked
316	Good	Cracked	Cracked Crazed	Cracked	Cracked	Cracked
317	Cracked	Cracked	Cracked Crazed	Cracked	Cracked	Cracked

Slips behave in a similar manner to what they do on biscuit, except that they crack worse and have a slight tendency to flake.

SERIES 45.

(On Leather Hard)

No.	Cone 4	Cone 6	Cone 8
310	Flaked Crazed	Flaked	Flaked
311	Flaked Crazed	Flaked	Good
312	Flaked Crazed	Flaked	Flaked
313	Cracked	Cracked	Cracked
314	Flaked	Flaked	Flaked
315	Flaked	Flaked	Flaked
316	Good	Good	Good
317	Flaked	Flaked	Flaked

Both unglazed and glazed slips flake some. Slip 313, which cracked, was dipped quite thick.

SERIES 46.

(On Leather Hard)

No.	Constant	Flint	Spar	Cone 3	Cone 5	Cone 8
318	English China ......35 English Ball ....10 Carbonate of Soda... 1	45	10	Good	Good	Good
319		40	15	Good	Good	Flaked
320		35	20	Cracked	Good	Good
321		30	25	Flaked	Flaked	Flaked
322		25	30	Good	Good	Good
323		20	35	Flaked	Good	Flaked
324		15	40	Good	Good	Good
325		10	45	Flaked	Good	Good

Slips have a slight tendency to flake. Flaking not bad. Some very good slips appear. All are opaque at Cone 2. Slips 323 to 325 are vitrified at Cone 6. Slips 321 to 325 are vitrified at Cone 8.

SERIES 47.

(On Leather Hard)

No.	Constant	Flint	Spar	Cone 4	Cone 5	Cone 8
326	English China ......45 English Ball ....10 Carbonate of Soda... 1	40	5	Good	Good	Good
327		35	10	Good	Good	Flaked
328		30	15	Good	Good	Good
329		25	20	Cracked	Cracked	Flaked
330		20	25	Flaked	Flaked	Flaked
331		15	30	Flaked	Flaked	Flaked
332		10	35	Good	Flaked	Flaked

Slips flake more than Series 46. Flaking seems to increase with increase in feldspar and increase in temperature. All are opaque at Cone 4. Slips 330 to 332 are translucent at Cone 9.

SERIES 48.

(On Leather Hard)

No.	Constant	Flint	Spar	Cone 4	Cone 6	Cone 8
333	English China ......55 English Ball ....10 Carbonate of Soda... 1	30	5	Cracked	Good	Cracked
334		25	10	Good	Flaked	Flaked
335		20	15	Flaked	Flaked	Good
336		15	20	Flaked	Good	Good
337		10	25	Flaked	Flaked	Flaked
338		5	30	Flaked	Flaked	Good

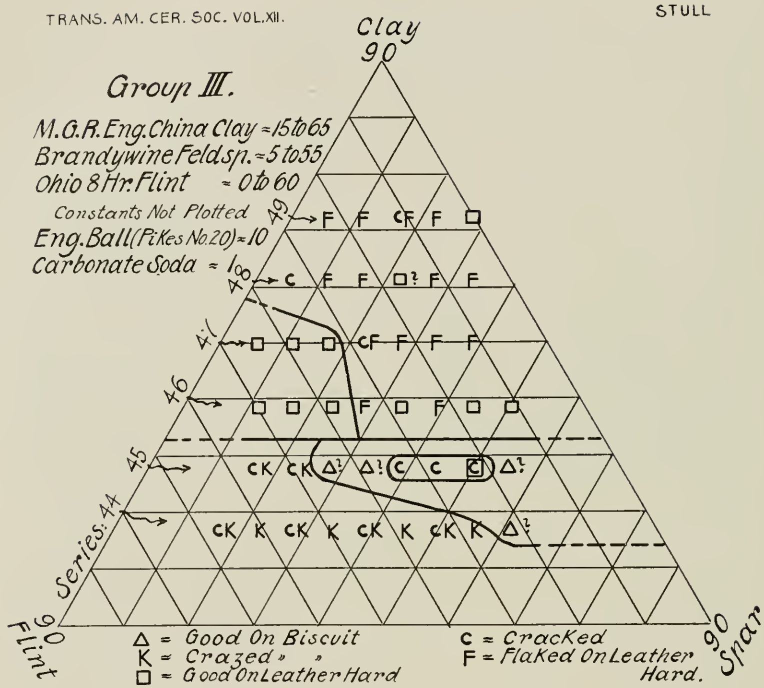
This series appears very similar to Series 47. All are opaque at Cone 8.

SERIES 49.

(On Leather Hard)

No.	Constant	Flint	Spar	Cone 4	Cone 6	Cone 9
339	English China ......35 English Ball ....10 Carbonate of Soda... 1	20	5	Good	Flaked	Flaked
340		15	10	Good	Flaked	Flaked
341		10	15	Cracked	Cracked	Flaked
342		5	20	Good	Flaked	Flaked
343		0	25	Good	Good	Good

Flaking in this series has increased over Series 48. All are opaque at Cone 9.



Conclusions on Group III.

Crazing and Cracking: The same conclusions on crazing found in Groups I and II also apply to Group III. Crazing of the slips has increased considerably over the two preceding groups. Since cracking is so erratic, no definite conclusions can be drawn.

Flaking: Flaking on leather hard trials during burning appears to be caused by too high clay content. Decreasing clay and increasing flint or feldspar, or both, decreases flaking during burning. Increasing flint overcomes flaking more effectively than increasing feldspar. With clay constant, decrease of flint and increase of feldspar increases flaking. The trials also show that flaking increases with increase in burning temperature.

The slips plotted as good on biscuit are in reality

doubtful. This field has dwindled considerably when compared to Groups I and II. A field of good slips on leather hard trials appears in an entirely different locality on the tri-axial diagram than that obtained in Group II.

The comparison of Groups II and III shows that the substitution of M. G. R. English China clay for North Carolina kaolin has increased crazing and cracking on biscuit trials, and increased flaking and cracking on leather hard trials. Examination of the trials shows that the English china clay produces slips which approach whiteness more closely and which vitrify at a lower temperature.

The limits of composition for good slips on biscuit body are doubtful. None of the slips were good on bone dry body. For leather hard body the limits of composition of good slips found in this group lie between:

M. G. R. English China Clay	35 to 55	
Brandywine Feldspar	5 to 20	
Ohio Flint	30 to 45	
Pikes No. 20 English Ball Clay	10	Constant
Carbonate of Soda	1	Constant

SERIES 50.

(On Biscuit)

Constant: Georgia Kaolin, 15; Tenn. Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 5		Cone 7		Cone 9	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
344	60	15	Crazed	Crazed	Crazed	Crazed	Good	Good
345	55	20	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed
346	50	25	Crazed	Crazed	Crazed	Good	Crazed	Good
347	45	30	Crazed	Good	Good	Good	Good	Good
348	40	35	Crazed	Good	Crazed	Good	Good	Good
349	35	40	Good	Good	Good	Good	Good	Good
350	30	45	Crazed	Good	Crazed	Good	Good	Good
351	25	50	Good	Good	Good	Good	Good	Good

Crazing decreases with decrease in flint and increase in Cornwall stone. Crazing also decreases with increase in temperature. All are opaque at Cone 4. No. 351 is translucent at Cone 7. Slips 349 to 351 are translucent

at Cone 9. No. 351 without glaze has a beautiful porcelain texture at cones 7 and 9. Its texture is a beautiful imitation of blue white marble.

Group IV. Series 51 to 56.

SERIES 51.

(On Biscuit)

Constant: N. C. Kaolin, 15; Tenn. Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 6		Cone 7		Cone 9	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
352	60	15	Crazed	Crazed	Crazed	Crazed	Crazed	Good
353	55	20	Crazed	Crazed	Crazed	Crazed	Crazed	Good
354	50	25	Crazed	Crazed	Crazed	Good	Good	Good
355	45	30	Crazed	Good	Good	Good	Good	Good
356	40	35	Crazed	Good	Crazed	Good	Good	Good
357	35	40	Good	Good	Good	Good	Good	Good
358	30	45	Crazed	Good	Crazed	Good	Good	Good
359	25	50	Good	Good	Good	Good	Good	Good

Aside from crazing, slips fit the body very well. Crazing decreases with decrease in flint, increase in Cornwall stone and increase in temperature. All are opaque at Cone 6. Slips 357 to 359 are vitrified at Cone 7. Nos. 355 to 359 are vitrified at Cone 9. Slip No. 359 has a beautiful parian marble texture at cones 7 and 9. Series not so white as Series 50.

SERIES 52.

(On Biscuit)

Constant: N. C. Kaolin, 25; Tenn. Ball, 10; Carbonate of Soda, 1.

No	Flint	Eng. C. Stone	Cone 6		Cone 7		Cone 9	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
360	50	15	Crazed	Good	Good	Good	Good	Good
361	45	20	Crazed	Good	Cracked	Good	Cracked	Good
362	40	25	Good	Good	Good	Good	Good	Good
363	35	30	Good	Good	Good	Good	Good	Good
364	30	35	Good	Good	Cracked	Good	Good	Good
365	25	40	Good	Good	Good	Good	Cracked	Good
366	20	45	Good	Good	Cracked	Good	Cracked	Good
367	15	50	Good	Good	Good	Good	Good	Good

Slips have a slight tendency to crack as the temperature of burning increases. All glazed slips were sound. All are opaque at Cone 6. Slips 365 to 367 are vitrified at Cone 7. Slips 363 to 367 are vitrified at Cone 9.

SERIES 53.

(On Biscuit)

Constant: N. C. Kaolin, 35; Tenn. Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng C. Stone	Cone 6		Cone 7		Cone 9	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
368	45	10	Cracked	Good	Cracked	Good	Cracked	Good
369	40	15	Cracked	Good	Cracked	Good	Cracked	Good
370	35	20	Cracked	Good	Cracked	Cracked	Cracked	Good
371	30	25	Cracked	Good	Good	Good	Good	Good
372	25	30	Cracked	Good	Good	Good	Good	Good
373	20	35	Good	Good	Good	Good	Cracked	Good
374	15	40	Good	Good	Good	Good	Good	Good
375	10	45	Cracked	Cracked	Cracked	Good	Cracked	Good

Cracking in this series has increased over that observed in Series 52. Cracking has evidently increased with increase in clay. Cracking decreases with decrease in flint and increase in Cornwall stone, but this is not borne out in all cases. Slips are all opaque at Cone 6. Slips 373 to 375 are vitrified at Cone 7. Nos. 371 to 375 are vitrified at Cone 9.

SERIES 54.

(On Biscuit)

Constant: N. C. Kaolin, 45; Tenn. Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 6		Cone 7		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
376	40	5	Cracked	Good	Cracked	Good	Cracked	Cracked
377	35	10	Cracked	Cracked	Cracked	Cracked	Cracked	Good
378	30	15	Cracked	Good	Cracked	Cracked	Cracked	Good
379	25	20	Cracked	Good	Cracked	Good	Cracked	Good
380	20	25	Cracked	Good	Cracked	Good	Cracked	Cracked
381	15	30	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
382	10	35	Cracked	Cracked	Cracked	Good	Cracked	Cracked

Cracking has increased. Glaze is not able to prevent cracking though it reduces it. Slips are all opaque at Cones 6 and 7. Slip 382 is translucent at Cone 8.

SERIES 55.

(On Biscuit)

Constant: N. C. Kaolin, 55; Tenn. Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 6		Cone 7		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
383	5	30	Good	Cracked	Good	Good	Good	Cracked
384	10	25	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
385	15	20	Good	Cracked	Cracked	Cracked	Good	Cracked
386	20	15	Cracked	Cracked	Good	Cracked	Good	Cracked
387	25	10	Good	Cracked	Cracked	Cracked	Good	Cracked
388	30	5	Cracked	Cracked	Cracked	Cracked	Good	Cracked

Cracking has steadily increased with increase of clay. Increase of temperature seems to increase cracking. All slips are opaque at Cone 8.

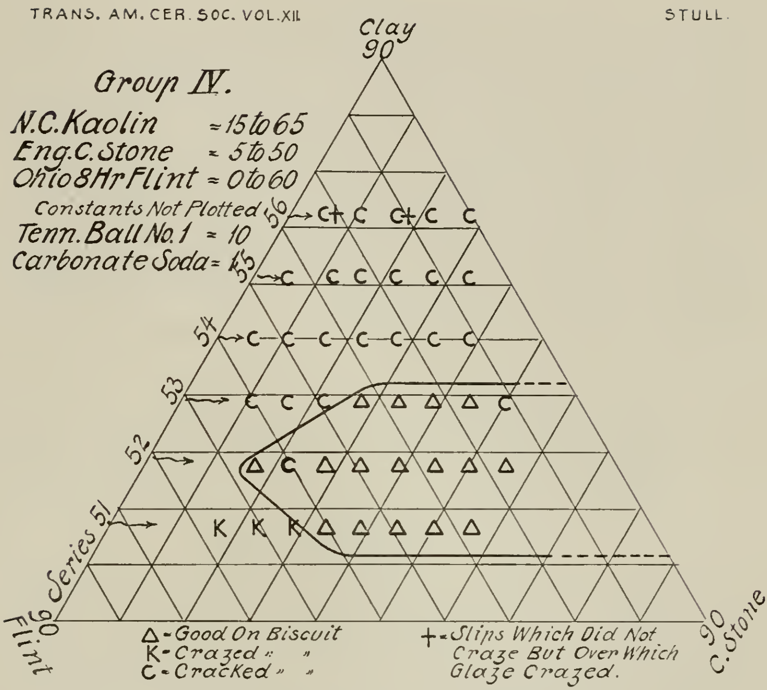
SERIES 56.

(On Biscuit)

Constant: N. C. Kaolin, 65; Tenn. Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 3		Cone 5		Cone 7	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
389	20	5	Cracked	Crazed	Crazed	Good	Good	Cracked
390	15	10	Cracked	Good	Cracked	Cracked	Cracked	Good
391	10	15	Cracked	Crazed Cracked	Cracked	Good	Cracked	Good
392	5	20	Cracked	Cracked	Cracked	Cracked	Cracked	Good
393	0	25	Cracked	Good	Cracked	Cracked	Cracked	Good

Slips are not cracked so badly as in Series 55, but probably due to the fact that the slips in Series 56 are burned at correspondingly lower temperatures. Slips do not craze but glaze shows crazing at Cone 2, in fine zig-zag lines.



Conclusions on Group IV.

Crazing: Crazing of slips decreases with decrease in flint and increase in clay or Cornwall stone, or both. Increasing clay is more effective in reducing crazing than increasing Cornwall stone. With flint constant, decreasing clay and increasing Cornwall stone increases crazing. These observations are the same as those noted in the three preceding groups, which shows the similar influences of feldspar and Cornwall stone upon crazing of slips. With respect to the temperature of burning the opposite is true. In Group IV, increasing burning temperature decreases crazing.

Cracking is due to high content of clay. Reducing clay and increasing flint or Cornwall stone, or both, reduces cracking. In one series evidence is presented that

increasing Cornwall stone is more effective in reducing cracking than increasing flint, though this is not borne out in all cases and is opposite to what was observed in Group I, with respect to flint and feldspar. Experience in the manufacture of enamel brick shows that replacement of Cornwall stone by flint reduces cracking.

In comparing Groups I and IV it is evident that the replacement of feldspar by Cornwall stone has given a smaller field of good slips on biscuit body, and has reduced crazing and increased cracking.

The limits of composition of good slips on biscuit body found in this group are:

North Carolina Kaolin	15 to 35	
English Cornwall Stone	15 to 50	
Ohio Flint	15 to 45	
Tennessee Ball Clay No. 1	10	Constant
Carbonate of Soda	1	Constant

Group V. Series 57 to 62.

SERIES 57.
(On Biscuit)

Constant: N. C. Kaolin, 15; English Ball No. 1, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 3 Unglazed	Cone 3 Glazed	Cone 5 Unglazed	Cone 5 Glazed	Cone 8 Unglazed	Cone 8 Glazed
394	60	15	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed
395	55	20	Crazed	Crazed	Crazed	Crazed	Crazed	Good
396	50	25	Crazed	Crazed	Crazed	Crazed	Crazed	Good
397	45	30	Crazed	Good	Crazed	Crazed	Good	Good
398	40	35	Crazed	Crazed	Crazed	Good	Crazed	Good
399	35	40	Crazed	Good	Good	Good	Good	Good
400	30	45	Crazed	Good	Crazed	Good	Good	Good
401	25	50	Good	Good	Crazed	Good	Good	Good
402	20	55	Good	Good	Crazed	Good	Good	Good

Slips craze quite badly. Glaze tends to prevent crazing of slips. Crazing decreases with decrease in flint, increases in Cornwall stone and increase in temperature. All are opaque at Cone 4. Nos. 401 and 402 are vitrified at Cone 6. Slips 399 to 402 vitrified at Cone 8.

SERIES 57.

(On Bone Dry)

No.	Cone 3		Cone 5		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
394	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed
395	Crazed	Crazed	Crazed	Good	Crazed	Good
396	Crazed	Crazed	Crazed	Crazed	Crazed	Good
397	Crazed	Good	Crazed	Good	Crazed	Good
398	Crazed	Good	Crazed	Good	Cracked	Cracked
399	Good	Good	Good	Good	Good	Good
400	Good	Good	Good	Good	Good	Good
401	Cracked	Good	Cracked	Good	Cracked	Cracked
402	Cracked	Good	Cracked	Cracked	Cracked	Cracked

Slips fit quite well. Crazing is practically the same as that observed in the same slips on biscuit. Cracking is slight.

SERIES 58.

(On Biscuit)

Constant: N. C. Kaolin, 25; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 4		Cone 6		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
403	50	15	Good	Good	Good	Good	Good	Good
404	45	20	Good	Good	Good	Good	Good	Good
405	40	25	Good	Good	Good	Good	Good	Good
406	35	30	Good	Cracked	Cracked	Good	Good	Good
407	30	35	Cracked	Cracked	Good	Good	Good	Good
408	25	40	Good	Good	Good	Good	Good	Cracked
409	20	45	Good	Good	Good	Good	Good	Good
410	15	50	Good	Good	Good	Good	Good	Good

Slips have slight tendency to crack when applied too thick, otherwise they seem to fit perfectly. All are opaque at Cone 6. Slips 407 to 410 are vitrified at Cone 8.

SERIES 58.

(On Bone Dry)

No.	Cone 4		Cone 6		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
403	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
404	Good	Cracked	Cracked	Cracked	Cracked	Cracked
405	Good	Good	Cracked	Cracked	Cracked	Good
406	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
407	Good	Good	Cracked	Cracked	Cracked	Good
408	Cracked	Cracked	Cracked	Good	Good	Good
409	Cracked	Cracked	Cracked	Cracked	Good	Cracked
410	Cracked	Cracked	Cracked	Cracked	Good	Cracked

Slips crack slightly in fine lines. Some are very good. These slips would probably work well for spraying on bone dry body.

SERIES 59.

(On Biscuit)

Constant: N. C. Kaolin, 35; English Ball No. 20, 10; Carbonate of Soda, 1.

No	Flint	Eng. C. Stone	Cone 2		Cone 7		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
411	45	10	Good	Cracked	Cracked	Cracked	Good	Cracked
412	40	15	Good	Good	Good	Cracked	Good	Good
413	35	20	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
414	30	25	Cracked	Cracked	Good	Cracked	Cracked	Cracked
415	25	30	Good	Cracked	Cracked	Cracked	Cracked	Cracked
416	20	35	Good	Cracked	Cracked	Cracked	Cracked	Cracked
417	15	40	Good	Cracked	Cracked	Cracked	Good	Cracked
418	10	45	Good	Good	Good	Good	Good	Good

Cracking has increased more than in Series 58. Cracking evidently increases with increase in clay. Replacement of flint by Cornwall stone does not seem to influence cracking.

SERIES 59.
(On Bone Dry)

No.	Cone 3		Cone 7		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
411	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
412	Good	Cracked	Cracked	Cracked	Cracked	Cracked
413	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
414	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
415	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
416	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
417	Cracked	Cracked	Good	Cracked	Cracked	Cracked
418	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked

Cracking has increased markedly over Series 58 on bone dry. As a rule the glaze reduces cracking.

SERIES 60.
(On Biscuit)

Constant: N. C. Kaolin, 45; English Ball No. 20, 10; Carbonate of Soda, 1.

No.	Flint	Spar.	Cone 3		Cone 7		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
419	35	10	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
420	30	15	Good	Cracked	Good	Cracked	Cracked	Cracked
421	25	20	Good	Cracked	Good	Cracked	Good	Cracked
422	20	25	Good	Cracked	Good	Cracked	Good	Cracked
423	15	30	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
424	10	35	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked

Slips crack badly. Difference in composition and heat treatment do not seem to influence the degree of cracking.

SERIES 61.
(On Biscuit)

Constant: N. C. Kaolin, 55; English Ball No. 20, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 5		Cone 7		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
425	30	5	Cracked	Cracked	Good	Cracked	Good	Cracked
426	25	10	Cracked	Cracked	Cracked	Cracked	Good	Cracked
427	20	15	Cracked	Cracked	Cracked	Cracked	Good	Cracked
428	15	20	Good	Cracked	Cracked	Cracked	Cracked	Cracked
429	10	25	Good	Cracked	Cracked	Cracked	Cracked	Cracked
430	5	30	Good	Cracked	Cracked	Cracked	Cracked	Cracked

Slips crack and curl up a little. Cracking seems to increase by replacement of flint by Cornwall stone.

SERIES 61.
(On Leather Hard)

No.	Cone 5		Cone 7		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
425	Good	Good	Good	Good	Good	Cracked
426	Good	Good	Good	Flaked	Good	Cracked
427	Good	Good	Good	Good	Good	Cracked
428	Good	Good	Good	Flaked	Cracked	Cracked
429	Flaked	Cracked	Flaked	Flaked	Cracked	Cracked
430	Good	Flaked	Good	Flaked	Cracked	Cracked

Slips were applied a little too thick. Some flaking occurs but not bad. Glaze flakes loose from slips in a few cases.

SERIES 62.
(On Biscuit)

Constant: N. C. Kaolin, 65; English Ball No. 20, 10; Carbonate of Soda, 1.

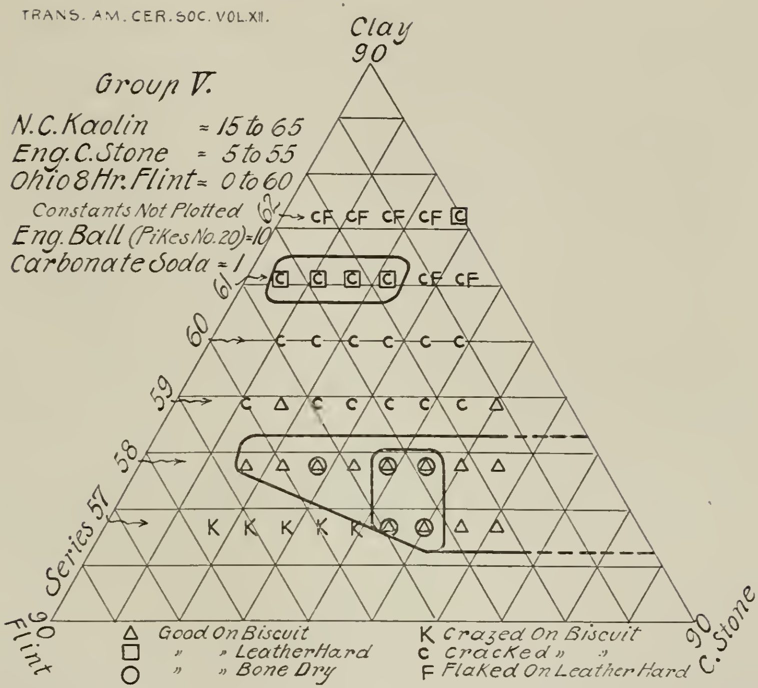
No.	Flint	Eng. C. Stone	Cone 5		Cone 7		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
431	20	5	Good	Cracked	Good	Cracked	Good	Cracked
432	15	10	Good	Cracked	Good	Cracked	Good	Cracked
433	10	15	Cracked	Cracked	Cracked	Cracked	Good	Cracked
434	5	20	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
435	0	25	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked

Series 62 on biscuit: This series cracks worse than any other series in the group. Slips curl up some.

SERIES 62.
(On Leather Hard)

No.	Cone 5		Cone 7		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
431	Good	Flaked	Flaked	Flaked	Flaked	Flaked
432	Flaked	Good	Flaked	Flaked	Flaked	Flaked
433	Flaked	Flaked	Good	Flaked	Flaked	Flaked
434	Good	Flaked	Good	Flaked	Cracked	Flaked
435	Good	Flaked	Good	Flaked	Good	Good

Slips flake some. Glaze also flakes a little. Slip No. 435, however, is very good at Cone 8.



Conclusions on Group V.

Crazing and Cracking: The observations on crazing and cracking in Group V are the same as those of Group IV.

Flaking: Flaking on leather hard body during burning increases with increase in clay. Reducing clay and increasing flint or Cornwall stone, or both, reduces flaking during burning. The opposite is true of flaking in dipping.

Comparing Groups V and IV shows a decrease in number of good slips on biscuit body by substituting Pikes No. 20 English ball clay for Tennessee No. 1 ball clay. Cracking and crazing have increased. (See comparison of Groups I and II.)

In comparing Groups V and II it is shown that the

substitution of Cornwall stone for feldspar has increased crazing and flaking. Cracking remains practically the same. The fields of good slips on biscuit and leather hard bodies are smaller. A few good slips on bone dry body appear in Group V which are lacking in Group II.

The limits of composition of good slips found in Group V are:

	On Biscuit	On Bone Dry	On Leather Hard
North Carolina Kaolin....	15 to 25	15 to 25	55 to 65
English Cornwall Stone...	15 to 55	25 to 45	5 to 25
Ohio Flint	15 to 50	25 to 40	0 to 30
Carbonate of Soda.......	10	10	10 } Constant
Pikes No. 20 English Ball.	1	1	1 } Constant

Group VI. Series 63 to 68.

SERIES 63.

(On Biscuit)

Constant: English China, 15; English Ball No. 20, 10; Carbonate of Soda, 1.

No.	Flint	Eng C. Stone	Cone 3 Unglazed	Cone 3 Glazed	Cone 6 Unglazed	Cone 6 Glazed	Cone 8 Unglazed	Cone 8 Glazed
436	60	15	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed
437	55	20	Good	Crazed	Good	Crazed	Good	Crazed
438	50	25	Crazed	Crazed	Good	Crazed	Good	Good
439	45	30	Good	Crazed	Good	Crazed	Good	Good
440	40	35	Crazed	Crazed	Good	Good	Good	Good
441	35	40	Good	Crazed	Good	Good	Good	Good
442	30	45	Good	Crazed	Good	Good	Good	Good
443	25	50	Good	Crazed	Good	Good	Good	Good
444	20	55	Good	Good	Good	Good	Good	Good

Slips high in flint craze. Glaze tends to prevent crazing of slips. Crazing decreases with decrease in flint, increase in Cornwall stone and increase in temperature. All slips are opaque at Cone 3. Slips 438 to 444 are vitrified at Cone 9.

SERIES 63.

(On Bone Dry)

No.	Cone 3		Cone 6		Cone 8	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
436	Crazed	Crazed	Crazed	Crazed	Crazed	Crazed
437	Crazed	Crazed	Crazed	Crazed	Crazed	Good
438	Good	Crazed	Good	Good	Good	Good
439	Good	Crazed	Good	Crazed	Good	Good
440	Good	Crazed	Good	Crazed	Good	Good
441	Good	Crazed	Good	Good	Good	Good
442	Good	Crazed	Good	Good	Good	Cracked
443	Good	Good	Cracked	Cracked	Cracked	
444	Good	Good	Good	Good	Crazed	Good

Crazing of slips practically the same as that observed in the same series on biscuit. Slips fit body very good, though not perfectly.

SERIES 64.

(On Biscuit)

Constant: English China, 25; English Ball No. 20, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 3		Cone 6		Cone 8	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
445	50	15	Good	Crazed	Good	Crazed	Good	Crazed
446	45	20	Good	Crazed	Good	Crazed	Good	Crazed
447	40	25	Good	Crazed	Good	Crazed	Good	Good
448	35	30	Good	Good	Good	Good	Good	Good
449	30	35	Good	Good	Good	Good	Good	Good
450	25	40	Good	Good	Good	Good	Good	Good
451	20	45	Good	Good	Good	Good	Good	Good
452	15	50	Good	Good	Good	Good	Good	Good

Slips fit body perfectly aside from crazing. Crazing decreases with decrease in flint and increase in Cornwall stone. All are opaque at Cone 2. Slips 448 to 452 are vitrified at Cone 6. Slips 446 to 452 are vitrified at Cone 7.

SERIES 64.

(On Bone Dry)

No.	Cone 2		Cone 6		Cone 7	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
445	Good	Crazed	Good	Crazed	Cracked	Crazed
446	Cracked	Cracked	Cracked	Crazed	Cracked	Crazed
447	Cracked	Crazed	Cracked	Crazed	Cracked	Good
448	Cracked	Crazed	Cracked	Good	Cracked	Cracked
449	Crazed	Crazed	Cracked	Cracked	Cracked	Cracked
450	Cracked	Cracked	Cracked	Cracked	Cracked	Cracked
451	Cracked	Good	Good	Good	Good	Good
452	Good	Cracked	Cracked	Good	Cracked	Good

The cracking, which is of the so-called "crowsfoot" type, is not bad. Variation in composition and temperature do not seem to influence the degree of cracking. No. 451 is very good at Cones 6 and 7.

SERIES 64.

(On Leather Hard)

No.	Cone 2		Cone 6		Cone 7	
	Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
445	Flaked	Flaked	Flaked	Flaked	Flaked	Flaked
446	Good	Flaked	Good	Flaked	Good	Flaked
447	Good	Good	Good	Good	Good	Flaked
448	Good	Good	Good	Good	Good	Flaked
449	Good	Good	Good	Good	Flaked	Flaked
450	Good	Good	Good	Flaked	Good	Flaked
451	Good	Good	Good	Good	Good	Good
452	Good	Good	Good	Good	Good	Good

Flaking appears to decrease with decrease of flint and increase in Cornwall stone. Glaze tends to reduce the degree of flaking, but not to overcome it. A subsequent examination of duplicate trials showed that slips were imperfectly bonded before burning since slips could be flaked off in small patches by pressing with the thumb nail.

SERIES 65.

(On Leather Hard)

Constant: English China, 35; English Ball No. 20, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 4		Cone 6		Cone 7	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
453	45	10	Good	Good	Good	Flaked	Good	Flaked
454	40	15	Good	Flaked	Flaked	Flaked	Good	Good
455	35	20	Good	Flaked	Good	Flaked	Good	Flaked
456	30	25	Good	Good	Good	Good	Good	Good
457	25	30	Good	Good	Good	Good	Good	Good
458	20	35	Good	Good	Good	Good	Good	Good
459	15	40	Good	Good	Good	Good	Good	Good
460	10	45	Good	Good	Good	Good	Good	Good

Flaking is less than in Series 64. Flaking decreases with decrease in flint and increase in Cornwall stone. Slips 456 to 466 are good hard slips at Cone 7. No. 460 is a dense white porcelain.

SERIES 66.

(On Leather Hard)

Constant: English China, 45; English Ball No. 20, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 2		Cone 6		Cone 7	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
461	40	5	Good	Good	Good	Good	Good	Good
462	35	10	Good	Good	Good	Good	Good	Good
463	30	15	Good	Flaked	Flaked	Flaked	Good	Flaked
464	25	20	Good	Good	Good	Good	Good	Good
465	20	25	Good	Good	Good	Good	Good	Good
466	15	30	Good	Good	Good	Good	Good	Good
467	10	35	Good	Good	Good	Good	Good	Good

Slips fit body very well. Slip No. 463 is the only one that showed any signs of flaking. Glaze has a tendency to flake on the slips. Slips 464 to 467 are excellent as to fit, color and hardness.

SERIES 67.

(On Leather Hard)

Constant: English China, 55; English Ball No. 20, 10; Carbonate of Soda, 1.

No	Flint	Eng. C. Stone	Cone 4		Cone 6		Cone 7	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
468	30	5	Good	Good	Good	Good	Good	Good
469	25	10	Good	Good	Good	Good	Good	Good
470	20	15	Good	Good	Good	Good	Good	Good
471	15	20	Good	Good	Good	Good	Good	Good
472	10	25	Good	Good	Good	Good	Good	Good
473	5	30	Good	Good	Good	Good	Good	Good

All slips fit body perfectly. No cracking or flaking could be detected. This is the best series in the group. Slips 470 to 473 are especially good at Cones 6 and 7.

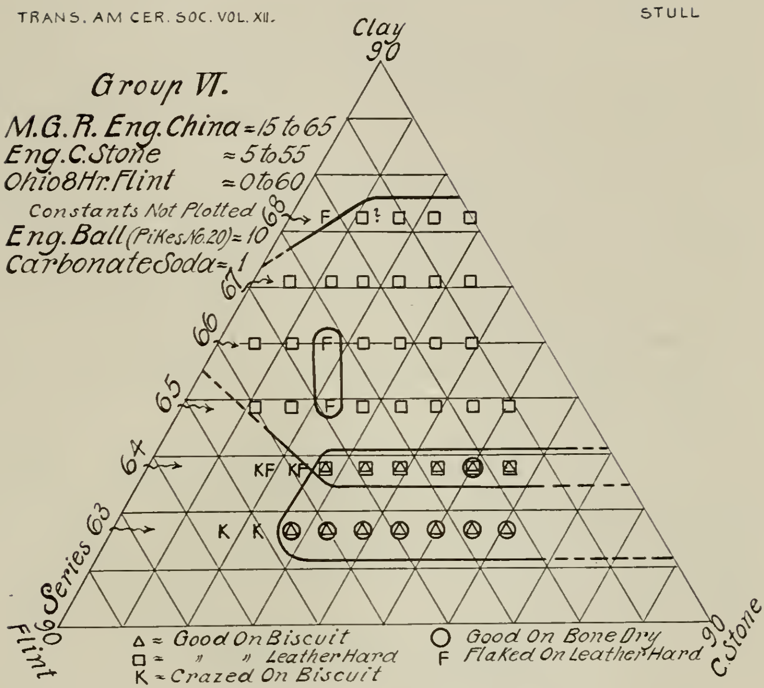
SERIES 68.

(On Leather Hard)

Constant: English China, 65; English Ball, 10; Carbonate of Soda, 1.

No.	Flint	Eng. C. Stone	Cone 4		Cone 6		Cone 7	
			Unglazed	Glazed	Unglazed	Glazed	Unglazed	Glazed
474	20	5	Good	Good	Flaked	Flaked	Flaked	Flaked
475	15	10	Good	Flaked	Flaked	Flaked	Flaked	Flaked
476	10	15	Good	Good	Good	Good	Good	Good
477	5	20	Good	Good	Good	Good	Good	Good
478	0	25	Good	Good	Good	Good	Good	Good

Slips high in clay and flint have a tendency to flake. Decrease of flint and increase of Cornwall stone has reduced flaking. Slips 477 and 478 are very good.



Conclusions on Group VI.

Crazing: Practically the same conclusions on crazing of the slip apply in this group as those observed in Groups IV and V.

Cracking: Very little cracking occurred in slips applied to bone dry body. No cracking occurred in slips applied to biscuit and leather hard bodies.

Flaking: Slips both low and high in clay showed a tendency to flake. Evidently slips low in clay were imperfectly bonded before burning. Flaking decreases with decrease in flint and increase in Cornwall stone.

A comparison of Groups VI and V shows that the substitution of M. G. R. English China clay for North Carolina kaolin has decreased crazing, cracking and flaking. The fields of good slips on biscuit body are practi-

cally the same size. A larger number of good slips appear on bone dry body, and the field of good slips on leather hard body has expanded to a comparatively large area. The slips are also superior in whiteness and vitrify at lower temperatures.

A comparison of Groups VI and III shows that the substitution of English Cornwall stone for feldspar has decreased crazing, cracking and flaking. The fields of good slips on biscuit and leather hard bodies have increased and good slips on bone dry were obtained, which are absent in Series III.

The limits of composition of good slips found in Group VI are:

	On Biscuit	On Leather Hard	On Bone Dry
M. G. R. English China Clay.	15 to 25	25 to 65	15 to 25
English Cornwall Stone.....	25 to 55	5 to 50	25 to 55
Ohio Flint	15 to 50	0 to 45	20 to 50
Pikes No. 20 Eng. Ball Clay.	10	10	10
Carbonate of Soda	1	1	1

GENERAL DEDUCTIONS.

From previous practical experience in the manufacture of enamel brick and from the foregoing investigations, the following rules are given for overcoming defects in enamel brick slips:

Defects Arising in the Application of the Slips and Remedies for the Same.

Principal Defects	Causes	Remedies
Pinholes	1. Using freshly made slips.	1. Age slips a week or more.
	2. Dust on the surface of brick.	2. Remove all dust or scrub the surfaces to be dipped.
	3 Pinholes in the surface of the brick.	3. Scrub surfaces to be dipped.
	4. Bad dipping.	4. (See Fig. 1, p. 717.)
Cracking	5. Too high content of clay in slip.	5. Reduce clay and increase the non-plastic portion, or add a soluble material as carbonate of soda, borax or silicate of soda.
	6. Slips too high in China clay or kaolin.	6. Decrease China clay or kaolin and increase ball clay, or add a soluble material.
	7. Allowing leather hard body to get too dry before dipping.	7. Dip brick in a softer condition.
	8. Applying slip too thick.	8. Do not apply slip over .05 of an inch thick.
	9. Too fine grinding of slip.	9. Blunge slips instead of grinding.
Flaking	10. Using slips too low in clay.	10. Increase clay and decrease non-plastic portion.
	11. Slips too high in China clay or kaolin.	11. Decrease China clay or kaolin and increase ball clay.
	12. Oil or dust on dipping surface.	12. Scrub surfaces to be dipped.
	13. In dipping on leather hard; dipping before brick have hardened sufficiently.	13. Allow brick to reach a firm leather hard condition before dipping.

Slip Defects Arising in Burning and Remedies for the Same.

Principal Defects	Causes	Remedies
Crazing	14. Slips too high in flint.	14. Reduce flint and increase clay, feldspar or Cornwall stone.
	15. Slips too high in feldspar or Cornwall stone.	15. Reduce feldspar or Cornwall stone and increase clay.
	16. With feldspar as a flux; burning slips at too high a temperature.	16. Reduce burning temperature.
	17. With Cornwall stone as a flux; burning slips at too low a temperature.	17. Increase burning temperature.
Cracking	18. Too high content of clay in slips.	18. Reduce clay and increase flint, Cornwall stone or feldspar.
	19. Too high content of feldspar or Cornwall stone in slips.	19. Reduce feldspar or Cornwall stone and increase flint.
Flaking	20. Dipping slips too thick.	20. Same as No. 8.
	21. Too high content of clay in slips.	21. Reduce clay and increase Cornwall stone, flint or feldspar.
	22. Too high content of feldspar in slips.	22. Reduce feldspar and increase Cornwall stone.
	23. Too high content of flint in slips.	23. Reduce flint and increase Cornwall stone.
	24. Burning slips at too high a temperature.	24. Reduce burning temperature.

SLIPS TESTED AS ENGOBES FOR STONEWARE.

The problem of producing a slip or engobe to be used as a white lining for stoneware was confronted. Slips No. 292, 298, 464 and 470 were selected as the starting point. These slips were applied to three different stoneware clays, viz.: Whitehall clay from Whitehall, Ill., having a comparatively high shrinkage; Macomb clay of medium shrinkage from Macomb, Ill.; Bloomingdale clay having a comparatively low shrinkage from Bloomingdale, Ind.

Trials were made in the form of cups, jiggered in one piece. Cups were taken from the molds, finished leather

hard, and slips applied to the inside in two coats. Over this a clear glaze was applied in one coat. The slip and glaze were scraped off at the outside rim. A brown glaze was applied to the outside by sinking the cup down into

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Stoneware Cup With White Engobe And Clear Glaze Inside And Brown Glaze Outside.

the glaze until the brown glaze touched the white slip and glaze extending over the rim. The cups were dried and burned at Cone 3. All four slips worked perfectly on all three stoneware bodies.

DISCUSSION.

Mr. Ramsay: There is a lot I would like to say on this subject, as it is an interesting one, but the trouble we have in the enamel brick business is not with the slips but in the cost of manufacture and results out of kilns.

I know Mr. Stull has put a good deal of time and work on his paper, and I agree with him on many of his results. To get a slip as near to the clays as possible you have to use lime, and when that is added it changes the results entirely. He made the claim that the slip will peal off with the dry clay. I would like to take exception to the

remark for the reason that ball clay will not come off. With China clay it will come off, but by a mixture of both it will not come off.

Mr. Stull: I do not think Mr. Ramsay's statement is antagonistic to what has been brought out in my paper. If a slip is high enough in ball clay it will cling to the body. Enamel brick makers as well as potters are limited in the amount of ball clay they can use on account of the bad color it imparts. For this reason I used ten per cent ball clay as the high limit in all slips.

It is quite essential to have some ball clay in the slip, but as a rule the less ball clay present the better color you get. My experience shows that a slip made from ball clay will stick very well but will crack badly. Ball clay possesses better adhesive qualities than China clay or kaolin, and seems to adjust itself better to the body both in drying and burning.

Mr. Ashley: I think to slightly increase the China clay slip by adding a small quantity of silicate of soda, will give some of the general characteristics of ball clay.

Mr. Ramsay: It may be in certain respects. If you add a certain percentage of silicate of soda you destroy the working qualities as regards the dipping. I suppose the idea is to decrease the water content and that only affects the drying shrinkage. There is no effect afterwards, of course, and I think the difference is so slight that it is hardly worth trying.

Mr. Stull: My experience in using silicate of soda was that it caused the slip to settle very rapidly and cake hard at the bottom. It requires constant agitation to keep the slip in suspension. Perhaps I was using too high a percentage, although it was only 3/8 of one per cent, however.

Mr. Ashley: I would suggest that even 1/10 of one per cent of silicate of soda acts very vigorously on clay, and we should experiment with 1/100 of one per cent rather than 1/10.

Mr. Worcester: I would like to ask Mr. Stull if he has studied the hardness of these slips with the various contents of spar. In some work we have been doing at Ohio State that was one of the requirements to produce a hard or nearly steel hard slip and I, of course, am very much interested, and was wondering if Mr. Stull had observed this point in particular or at all.

Mr. Stull: When each slip was shaken up and turned out of the can before dipping, a little of it was cast into trials, 1¾″ long, ½″ wide and ¼″ thick. These were placed in the sagger and burned with the dipped trials and used to determine the porosity. It was desirable to know what was the limit of porosity for these slips which would withstand the freezing test. That part of the work is under way at the present time.

Mr. Stover: I would like to ask what percentage of absorption you got, or was it around 1%? You spoke of making trials for absorption for your slips and that would follow in your paper. I happen to be looking along that line just now and would like to know.

Mr. Stull: There are two methods of determining the porous nature of brick. One is the percentage of absorption and one is the percentage of porosity. The absorption, as we know, is usually determined by weighing the brick dry then soaking it 48 hours and weighing it again. By observing the increase in weight and dividing that increase by the weight of the brick gives what is called percentage absorption. The percentage porosity is approximately 2½ times percentage absorption. The porosity of these slips was determined by Prof. Purdy's formula. The porosities of the slips have varied according to the kind and amount of flux and the temperature of burning. Perfect fitting slips were obtained from as soft as chalk up to a hard vitrified and glossed condition.

Mr. Stover: And do you not remember in figures what the result was?

Mr. Stull: No, I do not.